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Decision Support

# The impact of mismeasurement in performance benchmarking: A Monte Carlo comparison of SFA and DEA with different multi-period budgeting strategies

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ABSTRACT

Performance-based budgeting has received increasing attention from public and for-profit organizations in an effort to achieve a fair and balanced allocation of funds among their individual producers or operating units for overall system optimization. Although existing frontier estimation models can be used to measure and rank the performance of each producer, few studies have addressed how the mismeasurement by frontier estimation models affects the budget allocation and system performance. There is therefore a need for analysis of the accuracy of performance assessments in performance-based budgeting. This paper reports the results of a Monte Carlo analysis in which measurement errors are introduced and the system throughput in various experimental scenarios is compared. Each scenario assumes a different multi-period budgeting strategy and production frontier estimation model; the frontier estimation models considered are stochastic frontier analysis (SFA) and data envelopment analysis (DEA). The main results are as follows: (1) the selection of a proper budgeting strategy and benchmark model can lead to substantial improvement in the system throughput; (2) a "peanut butter" strategy outperforms a discriminative strategy in the presence of relatively high measurement errors, but a discriminative strategy is preferred for small measurement errors; (3) frontier estimation models outperform models with randomly-generated ranks even in cases with relatively high measurement errors; (4) SFA outperforms DEA for small measurement errors, but DEA becomes increasingly favorable relative to SFA as the measurement errors increase.



## 1. Introduction

Performance assessment of production and services is becoming an increasingly important managerial activity as public and for-profit organizations turn to performance-based budgeting in an effort to optimize the allocation of funds across their individual producers. The performance-based budgeting technique is clearly applicable and adaptable to many practical situations. One example is the allocation of an energy conservation program budget and assignment of appropriate energy quotas to the individual plants in a global automotive manufacturing company. The common practice in setting energy quotas is to apply the peanut butter approach,[1] in which the limited total budget is simply divided among individual plants in proportional to their production sizes along with an equal percentage of energy reduction quota (e.g., a 4% cut in the energy cost per production unit from the previous year), without considering the different energy saving potentials of the various plants. For example, certain plants may already have implemented aggressive energy saving programs and reached a point of diminishing returns, while other plants barely met (or even failed to meet) their allocated reduction quotas in previous years, carrying the remaining energy saving potential over to the next year. In such cases, the peanut butter approach may not serve to optimize the overall system performance or lead to efficient use of a limited budget. It would be far more desirable to allocate relatively low energy saving targets and low budgets to best-practice plants while allocating aggressive energy saving targets to inefficient plants along with high budgets to encourage major changes in their energy conservation practices.

The effectiveness of performance-based budgeting depends on the accuracy of the performance assessment in distinguishing between best-practice and inefficient producers. There are two major approaches to frontier estimation – stochastic frontier

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[1] It is frequently used as a business term where it can refer to the efforts to apply the same tactics to all aspects or parts of a business. As a person makes a peanut butter sandwich by spreading the butter thin evenly on the bread, a business or a government may want to spread something (tactics, money, or tax break) evenly across all areas.

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analysis (SFA) and data envelopment analysis (DEA). The consensus in the performance benchmarking literature is that DEA is preferable in applications in which the frontier model cannot be expressed in algebraic form or does not have a known inefficiency distribution. The SFA method is preferable when certain classical assumptions are satisfied regarding the composite error terms, including the contributions from the inefficiency distribution and measurement errors. It has also been claimed that DEA has a comparative advantage in cases involving relatively small measurement errors due to the conceptual treatment of the errors, while the complementary SFA method has the advantage when the measurement errors are relatively high. A more thorough assessment of the two frontier estimation models may help managers responsible for performance-based budgeting to make more informed decisions regarding the most appropriate method for their particular circumstances.

Several studies have addressed the comparative advantages of stochastic versus deterministic frontier estimation. Banker, Gadh, and Gorr (1993) and Banker, Charnes, Cooper, and Maindiratta (1987) compared the efficiency estimation accuracy of corrected ordinary least squares (COLS) and DEA using Monte Carlo methods. The results indicated that DEA outperformed COLS in most cases and that COLS failed to distinguish between the measurement error and inefficiency. However, both frontier models failed as the measurement errors became large for all of the experimental scenarios considered. These results contradicted the traditional view favoring the use of stochastic frontier models. The DEA method has been criticized previously for its neglect of measurement errors; Greene (1993) even suggested that econometricians have abandoned the deterministic frontier model because it does not consider measurement errors. Gong and Sickles (1992) demonstrated the superiority of the SFA approach using Monte Carlo analysis; however, their results were criticized because of their assumption that the efficiency of the firm remains constant over time. In reality, the efficiency of a firm varies over time due to a variety of exogenous and endogenous factors. Ruggiero (1999) conducted another Monte Carlo analysis in which previous comparative studies were extended to include more general experimental scenarios and discovered that the deterministic frontier model which ignores the impact of measurement error is not as limited as the main criticism against the deterministic models stated negatively, but rather outperformed the stochastic frontier analysis model from the average rank correlation perspective.

Mixed results have therefore been obtained concerning the comparative advantages of stochastic versus deterministic frontier estimation. Nonetheless, one consistent finding is that DEA remains attractive as a frontier model, especially when the measurement errors become large. The traditional criticism of DEA based solely on the conceptual treatment of the errors should therefore be reconsidered. Another consistent finding is that as the measurement errors increase, the accuracy of the performance measurement decreases in both models. However, very little comparative research has been performed to date on how mismeasurement by frontier estimation models impacts the capital budget allocation and degree of system optimization.

Several studies in the DEA literature have addressed resource allocation based on efficiency analysis using variants of the DEA method. The goal of these studies is to balance the desires of two management layers, a central management authority and a set of operating units, by allocating the available resources in an optimal fashion. The balance is achieved by adjusting the input and output in such a way that the efficiency of each operating unit is maintained (the desire of the operating units) while the total output of units is maximized (the desire of the central management). Korhonen and Syrjanen (2004) developed a formal interactive approach based on DEA and multiple-objective linear programming to identify the optimal allocation plan. In this approach, the units are assumed to be capable of modifying their production within a specified production possibility set. Yan, Wei, and Hao (2002) extended the "inverse" DEA method by introducing preference cone constraints to allow decision makers to incorporate their preferences into the resource allocation algorithm. Li and Cui (2008) investigated an "efficient-effective-equality" resource allocation framework consisting of a DEA-based method leveraging many existing resource allocation algorithms. However, these DEA-based resource allocation approaches assume that sector-level decision making units are able to modify their production plants in a timely manner following instructions from the central management. In practice, this sort of rapid production plan modification is only possible in service firms such as supermarket chains, banks, universities, hospitals and tourist agencies. In the manufacturing industry, for instance, plants generally require a long time to adjust to new production plans, and the time required for a particular unit can vary depending on its operating conditions.

DEA has many opportunities and challenges under the multi-criteria environment. Mehdiabadi, Rohani, and Amirabdollahiyan (2013) proposed a new approach to combine DEA and Order Preference by Similarity to Ideal Solution (TOPSIS) to rank various industries which is also a multiple criteria decision making problem. Das, Sarkar, and Ray (2013) extended the proposed approach by Mehdiabadi et al. (2013) into fuzzy AHP–DEA-TOPSIS methodology which is applicable to any multiple criteria decision making problem due to its generic nature. Makui and Momeni (2012) considered similarities between multi-criteria decision making and DEA and tried to interpret decision makers preferences in UTA-STAR method using the common set of weights (CSW) in DEA.

The purpose of this paper is to perform a Monte Carlo analysis of different frontier estimation models combined with different multi-period budgeting strategies and to provide a set of decision rules for selecting the budgeting strategy and benchmark model that are most appropriate for a specified set of circumstances. Artificial measurement errors are included in the analysis.

The remainder of the paper is organized as follows. In Section 2, a replication study is performed to ensure the reliability of previous comparative study results on stochastic versus deterministic frontier estimation. Section 3 describes the experimental design and introduces the budgeting strategies, scenario generation methods and time-varying efficiency model used in this paper. The results of the experiments are presented in Section 4. An analytical proof is provided for the fact that a peanut butter strategy outperforms a discriminative strategy in the presence of large measurement errors, while the discriminative strategy is preferred when the measurement errors are small. Section 5 concludes with a summary of the findings of this study and suggestions for future research directions.

## 2. Comparison of SFA and DEA

Previous findings from related studies indicate that DEA and SFA have comparative advantages in the cases of small and large measurement errors, respectively. However, the accuracy of both frontier models decreases as the measurement error increases. A replication study is performed in this section to assure the reliability of these findings and to raise concerns regarding the use of frontier estimation models for a performance-based budgeting system in the presence of measurement errors.

Assume that a large organization includes multiple individual producers and desires a systematic method for measuring and comparing the performance of the various producers in the organization, including cases in which the inputs and outputs of the individual producers have different scales. The organization